A field guide to the types of insects and mites infesting cured fish

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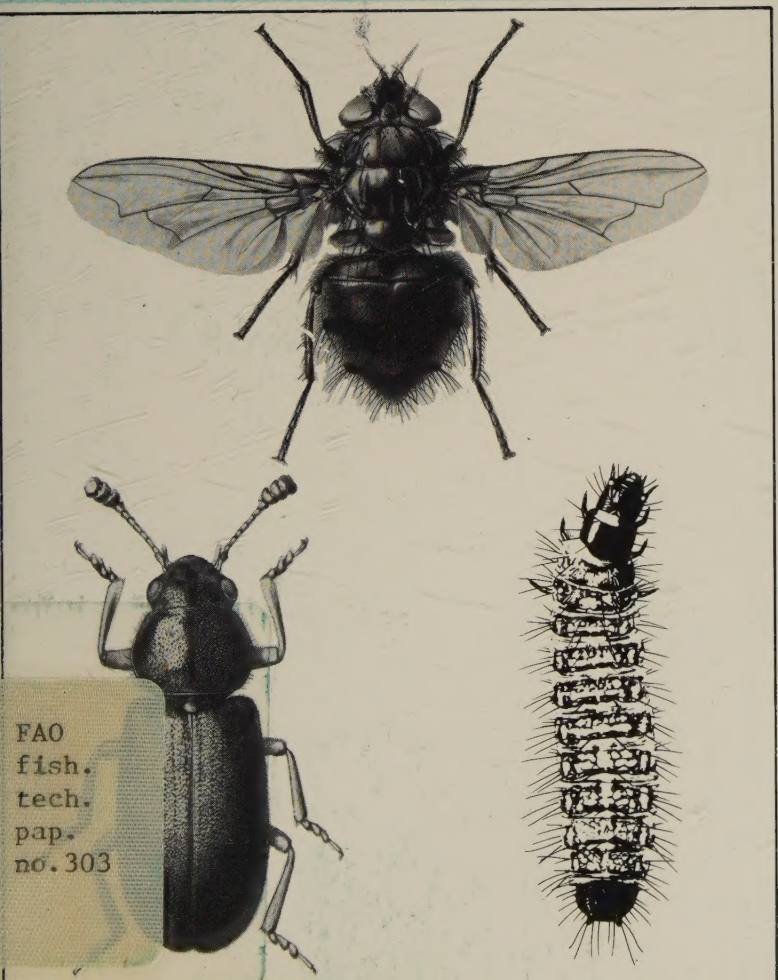

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FOOD
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OF THE
UNITED NATIONS

A field guide to the types of insects and mites infesting cured fish

Compiled by
C.P. Haines
and
D.P. Rees
Storage Department
Overseas Development
Natural Resources Institute
Slough
Berkshire, UK

Library
NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

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PREPARATION OF THIS DOCUMENT

This document was prepared under contract with FAO by the Overseas Development Natural Resources Institute (UK). The document was compiled by Dr C.P. Haines and Mr D.P. Rees of the Storage Department of ODNRI. The compilers are grateful to the sources cited under the figures for permission to reproduce the illustrations. The intention of this document is to provide information on the recognition, importance and biology of the main types of insects and mites infesting cured fish. This document will be particularly useful in training activities aimed at the prevention of post-harvest losses of cured fish. The FAO/DANIDA training project GCP/INT/391/DEN on Fish Technology and Quality Control has provided the funds for the preparation and printing.

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ABSTRACT

This field guide presents basic information on the recognition, importance and biology of the main types of insects and mites infesting cured fish. General information on the development and ecology of insects and mites is presented, together with advice on the collection, examination and preservation of specimens. The four main pest types (*Necrobia rufipes*, *Dermestes* spp., *Lardoglyphus* spp. and *Diptera*) are illustrated, with notes on their scientific and common names, appearance, life-cycles and ecology. Notes are also given on the damage these pests can cause to cured fish, and on ecological factors relevant to pest control and loss reduction. A selected bibliography is given for further reading.

CONTENTS

1. INTRODUCTION AND GENERAL INFORMATION 1

1.1 Importance of insects and mites on cured fish 1
1.2 Life-cycle and development of insects and mites 1
1.3 General ecology of insects and mites on cured fish 3
1.4 Collection and examination of insects and mites 4
1.5 Preservation of specimens 6
1.6 Main types of insects and mites found on cured fish 8

2. NECROBIA RUFIPES 10

2.1 Common names 10
2.2 Description and recognition features 11
2.3 Life-cycle 11
2.4 Ecology 11
2.5 Damage caused to cured fish 12
2.6 Ecological factors in relation to loss reduction 12

3. DERMESTS SPP. 14

3.1 Specific and common names 14
3.2 Description and recognition features 15
3.3 Life-cycle 16
3.4 Ecology 16
3.5 Damage caused to cured fish 17
3.6 Ecological factors in relation to loss reduction 17

4. LARDOGLYPHUS SPP. 19

4.1 Specific and common names 19
4.2 Description and recognition features 20
4.3 Life-cycle 20
4.4 Ecology 21
4.5 Damage caused to cured fish 21
4.6 Ecological factors in relation to loss reduction 22

5. DIPTERA 23

5.1 Scientific and common names 24
5.2 Description and recognition features 24
5.3 Life-cycle 25
5.4 Ecology 25
5.5 Damage caused to cured fish 26
5.6 Ecological factors in relation to loss reduction 26

6. BIBLIOGRAPHY 28

6.1 General entomology and acarology 28
6.2 Pests of cured fish (and other dried food) 28
6.3 *Necrobia rufipes* 29
6.4 *Dermestes* spp. 30
6.5 *Lardoglyphus* spp. 31
6.6 Diptera 32

FIGURES

Figure 1. Adult and larva of *Necrobia rufipes* 10
Figure 2. Adult and larva of *Dermestes maculatus* 14
Figure 3. Adult female of *Lardoglyphus konoi* and hypopus of *L. zacheri* 19
Figure 4. Adult of *Calliphora vicina* and larva of *Piophila casei* 23

TABLES

Table 1. Recognition of *Dermestes* species 15
Table 2. Flies found on cured fish 24

1. INTRODUCTION AND GENERAL INFORMATION

Insects and mites are often found infesting cured fish during and after processing, especially in the tropics and subtropics. The purpose of this field guide is to provide basic information on the appearance and ecology of the main types of insects and mites that cause losses to cured fish.

1.1 Importance of insects and mites on cured fish

Cured fish can suffer considerable loss of weight due to feeding damage by insect and mite pests. Under adverse conditions, quantitative losses of up to 30% due to fly damage during processing, and up to 50% due to beetle damage during storage for several months, have been reported. Under better conditions of processing and storage, the weight losses due to pest infestation are often much less than these extreme values, but they usually represent a significant wastage that could be reduced by prevention and control of pest attack. Published and unpublished reports of losses due to insect damage on cured fish have been summarized and discussed by FAO (1981).

Pest damage can also cause fragmentation of the cured fish (FAO, 1981), which can lead to quantitative loss of the smaller fragments (or downgrading of this fraction for use as animal feed) and loss of value due to quality reduction, since a higher price is often obtained for intact pieces of fish. Contamination by live or dead pests, or by their cast skins and frass (excreta), also causes a change in visual quality that may reduce the value of the fish. Additionally, insect and mite pests often transmit mould spores, and the heat and moisture produced by heavy infestations can create conditions suitable for mould growth on fish that has previously been dried.

1.2 Life-cycle and development of insects and mites

During development from egg to adult, insects and mites pass through several distinct stages. At the end of each stage, the old skin or cuticle (which forms a thin external skeleton) is shed and the next stage emerges with a fresh cuticle, which is initially elastic and thus allows growth before it hardens.

In many insects, including the beetles and flies found on cured fish, the immature stages are completely different in appearance from the adults; this type of life-cycle is called complete metamorphosis. In such insects, the egg hatches to produce a larva, which may have three pairs of jointed legs (e.g., most beetle larvae) or none (e.g., fly larvae). The larva is predominantly concerned with feeding and growth, and passes through several stages (instars) and moults before reaching full size. The last larval instar then changes into a legless pupa, which has no mouth. During the pupal stage, the body of the insect is reorganized into the adult form. This reorganization may be visible in pupae that have thin cuticles (e.g., beetle pupae) but hidden in others (e.g., those fly pupae in which the last larval cuticle is retained and becomes thickened as a puparium enclosing the pupa). Finally, the pupa moults to release the six-legged adult, which usually has one or two pairs of wings. The adult may feed on the same food as the larva or on a different food, or it may be short-lived and not feed at all; whether or not it feeds, the primary purpose of the adult stage is to reproduce and lay eggs. Detailed information on the structure and development of insects is given by Richards and Davies (1977, 1977 a).

In all mites and some insects, the immature stages are very similar to the adults in appearance, and also in their feeding habits and general behaviour; this type of life-cycle is called incomplete metamorphosis. In mites, the egg hatches into a six-legged larva, which then moults to produce a nymph with the eight legs that typify mites and other arachnids. Development then proceeds through one, two or three nymphal instars. The nymphs usually closely resemble the adult form, differing mainly in their smaller size and lack of external genital openings. In the species of mites commonly found on cured fish, there are two such normal nymphal stages, the protonymph and tritonymph. However, between these two normal stages a special type of deutonymph may occur - a hypopus, which has reduced mouth-parts and does not feed, but which has a number of suckers that allow it to cling to insects for dispersal. The last nymphal stage moults directly to the adult, which feeds in the same way as the normal nymphs but has fully-developed genitalia for reproduction. Further information on the development and biology of mites is given by Hughes (1976) and Krantz (1978).

1.3 General ecology of insects and mites on cured fish

Once an infestation of an insect or mite pest becomes established, its population tends to increase exponentially: i.e., the total numbers follow a geometric series over equal time intervals. Under ideal conditions for the particular pest species, the rate of increase may be very high. For example, in the common beetle pests of cured fish, the optimum rate of increase is 25-30 times in 4 weeks (Howe, 1965); i.e., at optimum conditions, one fertile female could give rise to 15 625-27 000 beetles in 12 weeks. Mite pests have even higher rates of population growth, with optimum rates of increase reaching many hundreds of times per month. If fish processing and storage conditions favour rapid development of pests it is essential that infestations are detected and controlled at an early stage, before large populations cause unacceptable levels of damage.

The actual rates of increase occurring in practice are, however, affected by many environmental factors. The more important of these factors are temperature, moisture, and the nature of the food (physical form and nutritional quality).

Insect and mite development can only occur within certain ranges of temperature, dependent on the species. Within its range, each pest species has an optimum temperature, usually less than 5°C below its maximum temperature limit, at which its rate of increase reaches a peak. Typically, for pests of cured fish, this optimum temperature is somewhere between 25° and 35°C. If exposed to temperature in excess of their maximum, insects and mites are eventually killed, unless they can disperse to cooler conditions. Below their optimum temperature, their rate of increase is progressively reduced until, at their minimum temperature limit, development ceases.

The development of insect and mite pests is similarly affected by moisture content and relative humidity. In particular, low moisture levels are an important limiting factor for most pests of cured fish and other dried food. The flies that infest moist partially-cured fish are especially susceptible to lack of moisture and usually cannot develop on the fully-cured product. Most of the other pests have high rates of increase on cured fish with moisture contents in equilibrium with 70-80% r.h. As the equilibrium r.h. is reduced below 70%, the rates of increase

of these pests (especially the flies and mites) are considerably reduced, and well-dried fish is much less susceptible to damage by most pests.

The physical nature of cured fish, especially the extent of any fragmentation, affects the availability of the flesh, and thus the rate of increase of pests feeding on it. This is likely to be especially true for mites. Different genera of cured fish have been found to vary in their susceptibility to infestation by beetles and mites, though the nutritional factors governing this variation have not been identified. The presence of the salt on salted cured fish reduces the rates of increase of most insects and mites, though the pest species vary in their response to different concentrations.

Further information on the effects of temperature, moisture and food type on pests of cured fish is given by FAO (1981).

1.4 Collection and examination of insects and mites

The main groups of pests of cured fish can usually be recognized with the naked eye or, preferably, by the use of a simple hand-lens, while they are still on the fish sample. However, if confirmation or more detailed identification is required, or if insects or mites other than the main pest types seem to be present, specimens should be collected for examination in the office or laboratory.

The simplest procedure, which reduces the amount of work in the field and also ensures that species are not overlooked, is to take samples of the infested fish, together with the pests, and place them in polythene bags (or similar sealed containers). The samples can then be examined in detail on a tray in the office or laboratory, and the pests extracted carefully. Collection of such samples may be essential if only the larvae or pupae of flies or beetles are present on the fish, and if detailed identification is required. Such specimens should be kept alive on the sample (in jars closed by pieces of cloth secured with rubber bands) until the immatures develop into adults, which are easier to identify.

Active adults of flies and beetles are usually easier to catch by using an entomologist's net, and transferring them to small tubes or jars. A suitable "butterfly" net can be purchased from biological equipment suppliers, or it can be

made locally by stitching soft mosquito-netting into the shape of a bag and fitting this onto a circular, ovate or triangular frame of metal or bamboo with a light wooden handle. This method is particularly useful for sampling pests that are flying around fish processing sites.

Insects and mites infesting flaked fish can be separated by sieving; the sieve aperture-size required will be governed by the average size of the fish flakes in relation to the size of the particular pests present.

In order to collect insect specimens from relatively intact fish pieces in the field, or to remove them from fish samples in the office or laboratory, one should use either lightweight forceps (preferably soft ones to reduce the likelihood of damaging the specimens) or a small aspirator. Mites can also be collected with an aspirator. It is possible to use a moistened fine artist's brush to collect small insects and mites, but this requires some practice.

The specimens should be placed in small labelled tubes (25 x 50 mm, or smaller). Most specimens will not be damaged by being kept in such tubes for up to 24 h but, if it is necessary to keep them for longer, preservative fluid should be added to the tube before sealing it, as described in section 1.5, below: this will kill the specimens and prevent their deterioration.

Samples or specimens should always be labelled, and notes made, at the time of collection in the field. The label attached to, or placed in, the sample bag or tube should give the most essential collection data (i.e., the location, type of cured fish, and date) in abbreviated form, together with a sample number. The full collection data, including notes on precise collection details, quality of fish, level of infestation, etc., should then be entered against the sample number in a notebook. It is not advisable to write only the sample number on the label, because field notebooks are sometimes lost or mislaid.

If a label is to be placed inside a sample tube containing preservative fluid, it must be written clearly with a pencil or with permanent black drawing ink; most other inks, whether water- or spirit-based, are dissolved by preservative fluids, and this includes the inks used in ballpoint pens. Further information on collecting and labelling of pest specimens is given by Oldroyd (1970), British Museum (Natural History) (1974), Hodges (1980) and Dobie *et al.* (1984).

In order to confirm, in the office or laboratory, to which main pest group a specimen belongs, a simple hand-lens or bench-lens may be necessary. In order to identify pests more precisely by using identification keys such as those given by Freeman (1980), Dobie et al. (1984) and Halstead (1986), it is usually essential to use a microscope. A cheap low-power "dissecting" microscope is normally sufficient. Identification of mites, however, by using keys such as those given by Hughes (1976), requires specialist knowledge and a high-power transmitted-light microscope.

1.5 Preservation of specimens

If insect and mite specimens are to be retained for further identification, or as reference specimens, or for any other reason, they must be preserved. If the specimens have already been placed in preservative at the time of collection, it is still usually advisable to transfer them to fresh preservative (and to remove any fish flakes or other debris). Adult flies (and other insects) are commonly preserved dry on entomological pins or stuck to card with a water-soluble glue (British Museum (Natural History), 1974). This technique is, however, unsuitable for long-term storage in warm humid climates, where the specimens may be destroyed by mould, and in many climates the dried insects are susceptible to attack by museum beetles and similar scavengers. It is therefore generally preferable to keep most insect and mite pests of cured fish in preservative fluid (as described below) in small labelled tubes. The main exception is that, if adult flies are to be sent to a museum or a specialist for identification, they should be dried and then packed gently in a small box between layers of tissue, as they lose their colour in preservative.

The best general-purpose preservative is Pampel's Fluid. This is prepared by mixing the following ingredients together (in parts by volume to give the quantity required) in the order shown: 30 parts water (preferably distilled); 15 parts 95% ethyl alcohol; 6 parts 40%(w/v) formaldehyde; and 4 parts glacial acetic acid. (Never start with the acid: always add it slowly after mixing the other ingredients.) If possible, let the mixture stand for a few days before use: the unpleasant smells of the acid and aldehyde will then have disappeared. If glacial acetic acid is not available, or is considered too dangerous to transport or stock, replace the water and concentrated acid in the above list with either 7.5 parts water and 26.5 parts 15% acetic

acid solution, or 14 parts water and 20 parts 20% acetic acid solution. If industrial acetic acid is not avilable, a similar (but weaker) preservative can be made by mixing: 35 parts strong vinegar (preferably white); 15 parts absolute (> 99.5%) ethyl alcohol; and 2.5 parts 40%(w/v) formaldehyde.

An alternative preservative, which is particularly suitable for mites and insect larvae, is Oudeman's Fluid. This is made by mixing together (as for Pampel's Fluid): 87 parts 70% ethyl alcohol; 5 parts glycerol; and 8 parts glacial acetic acid. Because of the high proportion of acid to water in this fluid, it is only possible to make it withough glacial acetic acid by using 25% acid solution and concentrated alcohol: 63 parts 95% ethyl alcohol (or 61 parts absolute alcohol plus 2 parts water); 32 parts 25% acetic acid solution; and 5 parts glycerol.

If Pampel's Fluid or Oudeman's Fluid cannot be prepared, then 70% ethyl alcohol or 10% formaldehyde can be used, though these both tend to harden specimens and the latter causes discoloration. In the absence of any of these preservatives, a colourless alcoholic liquor can be used, if available, but it should be noted that at normal strengths of only 40% alcohol this is not such an effective preservative.

As described earlier, the specimen tubes must be labelled and the labels must be written in pencil or black drawing ink. The tubes should be well-filled with preservative to cover and protect the specimens even when they are moved. A small wad of soft absorbent paper can be used to reduce the volume of preservative and restrict the movement of robust specimens, but care must be taken not to trap air-bubbles below the paper; this should not be done with delicate or small specimens (small insect larvae or mites) as they often become entangled in the fibres. The tube must be very well sealed to prevent evaporation or leakage of the preservative: cork stoppers should be sealed with melted wax, if possible, and rubber or plastic closures should be secured with adhesive tape.

If specimens are to be sent by post or courier to a specialist for identification, the tubes must be well protected from damage. A simple method using commonly-available materials is to bore a hole in a small block of expanded polystyrene packing, push the specimen tube entirely into the hole, and pack the block in a small cardboard box or a padded bag. Other methods are described by British Museum (Natural History) (1974), Hodges (1980) and Dobie _et al._ (1984).

1.6 Main types of insects and mites found on cured fish

The pests commonly found on cured fish are beetles (Coleoptera) or flies (Diptera), or mites (Acarina).

The adults of the beetles all have six legs, a large thoracic segment behind the head, and a pair of hard wing-cases (elytra) that cover much or all of the abdomen. These elytra are actually modified fore-wings; the hind-wings are normal but are usually completely hidden under the protective elytra, except in a few species which have no hind-wings. The larvae of the beetles normally have 3 pairs of jointed legs, one on each of the 3 segments behind the head, and sometimes have one or two horn-like protuberances at the end of the segmented abdomen. Some beetle larvae are covered densely with long hairs, but others are almost smooth. The main beetle pests of cured fish are Necrobia rufipes and Dermests species: these are described in sections 2 and 3 of this guide. Other beetle adults are sometimes found on cured fish. The anobiid Lasioderma serricorne (Fabricius), which is small (2.0-2.5 mm) and reddish-brown with its head partly hidden below the thorax, is a pest of many dried commodities and has been reported from cured fish in South Asia. Various species of predatory histerid beetles, especially species of Saprinus and its relatives, are occasionally found on cured fish, especially in association with infestations of Dermestes larvae on which they prey; these beetles are broadly oval, almost hairless, black and shining (sometimes with metallic lustre or pale spots), and the elytra are rather shorter than the abdomen (Hinton, 1945 a).

The adults of the flies all have six legs, large eyes, and one pair of membranous wings. Behind and slightly below the base of each wing is a small club-like structure (haltere) that may be partly concealed by a protruding lobe; the paired halteres are gyroscopic balancing organs and are modifications of the hind-wings. Fly larvae, often called maggots, have no legs, a very small head, and barely-visible mouthparts formed mainly of two hook-like mandibles. The larvae are generally cylindrical, though often tapering towards the head, and sometimes have numerous protuberances. The pupae are protected by hardened puparia, which are cylindrical with rounded ends and vary in colour according to species and age. All flies associated with cured fish are in the advanced suborder Cyclorrhapha, and the majority belong to the family Calliphoridae (the blow-flies, blue-bottles, greenbottles, and flesh flies). The common types of fly found on cured fish are described in section 5 of this guide.

Mites are very small (always less than 1 mm and usually less than 0.5 mm) and their thin-skinned oval bodies are usually a translucent creamish-white. Because of their small size, mites are often not noticed; if cured fish has a dusty rough-textured appearance, the "dust" may in fact be mites. Mites never have wings, and the segmentation of the body that is clear in most insects is not visible in mites. The larvae have only six legs, but the nymphal stages and adults have eight legs. Most of the species of mites that are pests on stored foods belong to the family Acaridae. On cured fish, the commonest acarids are species of Lardoglyphus, which are described in section 4 of this guide: other types of acarid, or similar pest groups, are rarely found on this commodity. Predatory mites, which are usually distinguishable by their long legs and fast movement, may occasionally be seen, but only in small numbers. Accurate identification of mites requires specialist knowledge.

2. NECROBIA RUFIPES

Necrobia rufipes (DeGeer) is a beetle of the family Cleridae and is the commonest species of Necrobia found on cured fish. Two related species, N. ruficollis (Fabricius) and N. violacea (Linnaeus), are only rarely found on this commodity.

Sources: Adult - by permission of Ministry of Agriculture, Fisheries and Food, U.K. (Crown Copyright); Larva - by permission of ICI Agrochemicals, U.K.

Figure 1. Dorsal views of adult (left) and larva (right) of *Necrobia rufipes*.

2.1 Common names

Copra beetle, Red-legged ham beetle [En]; Nécrobie à pattes rouge [Fr]; Schinkenkäfer, Koprakäfer [Ge]; Gorgojo de la copra [Sp].

2.2 Description and recognition features

ADULT - Shape as in Figure 1 (left). Length c. 4.5 mm. Upper surface of body (head, thorax, elytra) entirely shining metallic bluish-green. Underside of abdomen entirely dark blue. Legs bright reddish-brown or orange. Antennae mainly reddish-brown but with a dark brown or black club at the tip. Sides of thorax (especially) and elytra with stiff bristle-like hairs. Distinguished from adults of similar species by coloration described above: N. violacea has black or bluish legs and antennae; and N. ruficollis has reddish-brown thorax and base of elytra.

LARVA - Appearance as in Figure 1 (right). Typical beetle larva with three pairs of jointed legs; moderately hairy. Most of body creamish-grey with mottled violet-grey markings on the upper surface. Head, and upper surfaces of the 1st thoracic segment and the last large abdominal segment (the ninth), with brown hardened plates; 2nd and 3rd thoracic segments also with tiny brownish plates. Plate on last large abdominal segment with two horn-like protuberances which curve strongly upwards. Very difficult to distinguish from closely-related species of Cleridae, but easily distinguished from Dermestes larvae by coloration and normal amount of hairs, and from fly larvae by presence of legs and obvious head.

2.3 Life-cycle

Adult beetles feed on the surface of dried fish, and they lay their eggs in crevices in the fish. The larvae burrow deeply into the flesh; as well as feeding on the fish, they are predatory on the larvae of some flies, and on the eggs and larvae of Dermestes spp. The larvae pass through three or four instars. The last instar larva spins a cocoon in which pupation occurs: this may be within the fish flesh, or the larva may leave the fish and pupate in any dark crevice. The life-cycle takes about 6 weeks or longer depending on food type and physical conditions. Under optimum conditions, the rate of population increase is about 25 times per month. The adults fly actively and can thus easily disperse to new sources of food.

2.4 Ecology

The optimum temperature for development of N. rufipes is in the range 30-34°C, and the minimum temperature is 22°C; the maximum temperature limit is not known, but temperatures

above 40-42°C are likely to repel or prevent development of this pest. This beetle needs an equilibrium relative humidity of 50% or above. N. rufipes can therefore become a pest in tropical and subtropical climates, especially if ambient conditions are rather humid or the fish is not very well dried. It has a cosmopolitan distribution in warm climates.

N. rufipes is usually found in association with infestations of Dermestes spp.: its habitat requirements are similar to those of the tropical species of Dermestes, and it benefits from the availability of Dermestes larvae and eggs as prey.

2.5 Damage caused to cured fish

Feeding by larvae and adults of N. rufipes causes quantitative loss of dried cured fish, and also leads to fragmentation and to quality losses due to contamination by insect bodies and cast skins. The extent and value of losses due to N. rufipes infesting dried fish have not been assessed either in the laboratory or the field, but they will of course be directly related to the length of storage of the fish. When associated with Dermestes infestations, N. rufipes is usually in the minority but its contribution to the total beetle damage may be significant.

2.6 Ecological factors in relation to loss reduction

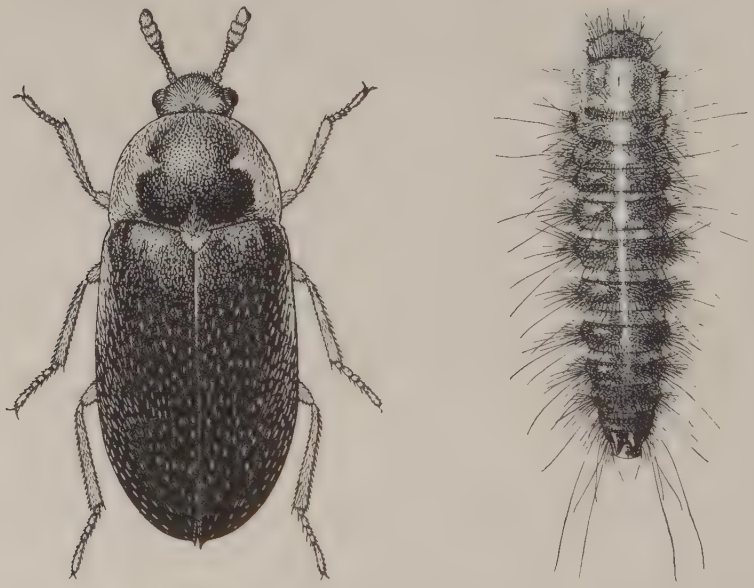
Initial infestation is usually due to invasion by flying and crawling adults, which lay their eggs on the partially or fully dried fish. Fly-screens around and over drying racks will reduce beetle infestation pressure during processing. Similarly, during storage and transport, the use of clean good-quality sacks will slow down rates of immigration of N. rufipes. Osuji (1975) found that cross-infestation by N. rifupes was reduced when jute sacks were lined with polythene and thick brown paper.

Although the upper lethal temperature for N. rufipes is not known precisely, temperatures above 45°C can be expected to kill or repel these beetles. Such temperatures can disinfest fish or delay invasion by N. rufipes, as long as they are achieved throughout the batch: if some of the fish remains at normal temperatures, the beetles will migrate to this. Very well dried fish reduces the rate of increase of N. rufipes populations.

Salting of fish gives considerable protection against N. rufipes, because larval development is severely retarded. In experiments, larval development took 85 days on fish with 3.5% salt content compared with 42 days on unsalted fish (Osuji, 1975 a).

3. DERMESTES SPP.

Species of Dermestes belong to the beetle family Dermestidae. Several species have been recorded infesting cured fish (or fishmeal): D. maculatus DeGeer, D. frischii Kugelann, D. ater DeGeer, D. carnivorous Fabr., D. lardarius L., D. haemorrhoidalis Küster, and D. peruvianus Laporte de Castelnau.



Source: Adult and larva - from Hinton (1945) by courtesy of the British Museum (Natural History)

Figure 2. Dorsal views of adult (left) and larva (right) of *Dermestes maculatus*.

3.1 Specific and common names

Dermestes spp.: Hide beetles [En]; Dermestes [Fr]; Speckkäfer [Ge]. D. ater: Black larder beetle [En]; Dermeste noir [Fr]. D. carnivorus: Dermeste carnivore [Fr]. D. frischii: Dermeste destructeur du cuir [Fr]. D. harmorrhoidalis: Black larder beetle [En]; Dermeste africain du lard [Fr]. D. lardarius: Bacon beetle, Larder beetle [En]; Dermeste du lard [Fr]; Speckkäfer [Ge]; Dermeste del tocino [Sp]. D. maculatus: Hide beetle, Leather beetle [En]; Dermeste des peaux [Fr]; Gorgojo del cuero [Sp]. D. peruvianus: Peruvian larder beetle [En]; Dermeste péruvien [Fr].

3.2 Description and recognition features

ADULT - Shape elongate oval, as shown in Figure 2 (left). Length 5.5-10.0 mm. Cuticle of upper surface of body black or dark brown, covered with black, whitish-grey, brown or yellowish hairs, which form a distinct pattern in some species. Underside of abdomen with black, whitish, brown or golden hairs, often forming a distinct pattern. Antennae rather short but with an obvious club at the tip. Distinguished from Necrobia spp. by the lack of metallic coloration, and larger size. The adults of the different species can be recognized by the characters listed in Table 1, but some of these can only be clearly seen with a low-power microscope; full identification keys are given by Freeman (1980) and Peacock (1975).

Table 1. Recognition characters for adults of the species of *Dermestes* recorded from cured fish.

Recognition characters	*Dermestes* species (see footnote)*						
	ma.	fr.	ca.	la.	at.	ha.	pe.
Each side of thorax with a broad band of dense whitish hairs	Yes	Yes	Yes	No	No	No	No
Extreme tip of each elytron (on the mid-line) with a sharp backwardly-pointing tooth	Yes	No	No	No	No	No	No
Underside of abdomen mainly white with black spots at the sides and a larger black patch at the tip of the last segment	Yes	Yes	No	No	No	No	No
Underside of abdomen mainly white with black spots at the sides but no black patch at the tip of the last segment	No	No	Yes	No	No	No	No
Underside of abdomen entirely dark brown or black	No	No	No	Yes	No	No	No
Underside of abdomen golden brown with rows of darker brown patches at each side and on both sides of the mid-line	No	No	No	No	Yes	No	No
Underside of abdomen reddish-brown with yellowish hairs	No	No	No	No	No	Yes	Yes
Elytra evenly dark brown or black (hairs mostly black with some whitish or yellowish, or hairs mostly fine and yellowish)	Yes	Yes	No	No	Yes	Yes	Yes
Elytra with front half reddish-brown and back half dark brown; hairs mainly black with small patches of white, but with a band of golden hairs near the front of the elytra	No	No	Yes	No	No	No	No
Elytra with front half clothed in yellowish hairs, except for a dark patch at each shoulder and three pairs of dark spots across the middle; back half of elytra clothed with black hairs	No	No	No	Yes	No	No	No
Hairs on elytra coarse and quite long, projecting over the back edges of the elytra as a thick fringe; these hairs mainly dark brown or black with yellowish hairs occurring singly	-	-	-	-	-	Yes	No
Hairs on elytra fine and short, not forming a fringe on the back edges of the elytra; these hairs mainly pale yellowish	-	-	-	-	-	No	Yes

* *Dermestes* species: ma. = *maculatus*; fr. = *frischii*; ca. = *carnivorus*; la. = *lardarius*; at. = *ater*; ha. = *haemorrhoidalis*; pe. = *peruvianus*

LARVA - Appearance as in Figure 2 (right). Thoracic segments with three pairs of jointed legs. Body densely covered with hairs of various lengths. Underside of body usually yellowish-brown, but upper surface of body mainly dark brown, often with a central yellowish line. Upper surface of last large abdominal segment (the ninth) with two long pointed horn-like protuberances, which may be partly hidden by surrounding hairs. Identification keys to the species are given by Hinton (1945) and Peacock (1975), but these require specialist knowledge. Dermestes larvae are easily distinguished from all others found on cured fish by their hairiness and dark colour.

3.3 Life-cycle

The adults feed on dried or drying fish, and the females lay their eggs in cracks in the flesh of the fish. The rate of egg-laying is greatly increased if water is available for the female to drink. The larvae burrow into the flesh as they feed on it. The larvae normally pass through five, six or seven instars, but the number of moults is higher under unfavourable conditions. The cast larval skins are commonly found in infested fish, and may be confused with the larvae. Before pupation, the last instar larvae burrow into solid material: this may be the flesh of the fish, but it is commonly the wood of drying racks or store structures, which may be seriously weakened by the tunnelling. The life-cycle of the major pest species takes about 5-7 weeks or longer depending on food type and physical conditions. Under optimum conditions, the rate of population increase of D. maculatus and D. frischii is about 30 times per month. Dermestes adults can fly and can thus easily disperse to new sources of food.

3.4 Ecology

The two commonest species on cured fish in warm climates, D. maculatus and D. frischii, have an optimum temperature in the range 30-35°C and a minimum of 20°C. They need an equilibrium relative humidity of 30% or above, and their optimum is about 75% r.h. D. ater and D. haemorrhoidalis seem to have a slightly lower optimum temperature in the range 27-30°C, but also have a minimum at about 40°C. They can develop in equilibrium relative humidites of at least 40% r.h. and above, with an optimum of about 75% r.h. D. lardarius and D. peruvianus have an optimum temperature of 25°C or slightly higher, and a minimum of about 15°C. They, also, can develop in humidities of at least 40% r.h., but their optimum seems to

near 80% r.h. Little is known about the physical requirements of D. carnivorus, but it is frequently found on cured fish in the hot humid climate of Indonesia.

D. maculatus and D. frischii are the commonest species that infest cured fish; D. maculatus is especially associated with freshwater fish and D. frischii is more common on marine fish, but these associations are not exclusive. The third commonest species in warm climates is D. ater, which is well-known as a pest of copra but is also often a significant pest of dried fish in the tropics. D. carnivorus seems to be an important pest of cured fish in Indonesia; it has also been recorded infesting dried fish in the Philippines and fishmeal in Pakistan. The remaining three species (D. lardarius, D. haemorrhoidalis and D. peruvianus) have only occasionally been recorded from dried fish or fishmeal, and are not significant pests of cured fish.

3.5 Damage caused to cured fish

Feeding by the larvae and adults of Dermestes spp. causes considerable quantitative loss of dried cured fish, and also leads to fragmentation. Quality loss may also be caused by the presence of insect bodies and cast skins. The extent and value of quantitative losses caused to dried fish by Dermestes spp. have been assessed by various investigators, and estimates range from negligible up to 50% weight loss, depending on length of storage, salt content, moisture content, climatic conditions, and general hygiene during processing and storage. Weight losses due to fragmentation have also been investigated, but the contribution of Dermestes spp. to this process has not been separately assessed. These loss estimates have been reviewed by FAO (1981). Additional costs may arise from damage caused to wooden drying racks and store structures by the mature larvae.

3.6 Ecological factors in relation to loss reduction

Initial infestation is often due to invasion by flying adults, which lay their eggs on the partially or fully dried fish. Fly-screens around and over drying racks may reduce beetle infestation pressure during processing. Similarly, during storage and transport, the use of clean good-quality sacks will slow down rates of immigration of Dermestes spp. Osuji (1975) found that cross-infestation by Dermestes spp. was reduced when jute sacks were lined with polythene and

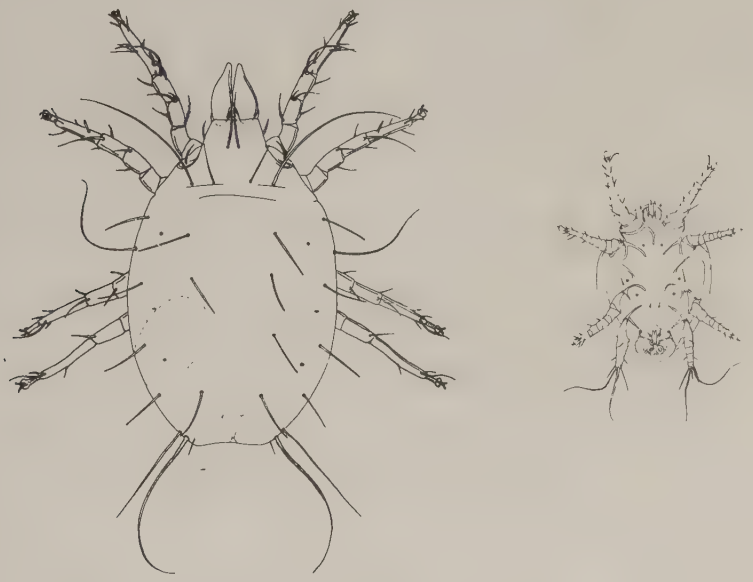
thick brown paper. Infestation may also be initiated by crawling larvae and adults present in fish residues, or by adults emerging from pupation chambers in wooden structures. The risk of such infestation can be reduced by improved hygiene and by treatment of the wooden structures with a recommended insecticide.

Development of D. maculatus and D. frischii is not possible at 40°C or above. The upper temperature limit for D. ater also seems to be close to 40°C, but the limits for D. haemorrhoidalis, D. lardarius and D. peruvianus appear to be lower. The limit for D. carnivorus is not known but is probably close to 40°C. Temperatures above 40°C can thus be expected to kill or repel all these beetles. Such temperatures can disinfest fish or delay invasion by Dermestes spp., as long as they are achieved throughout the batch: if some of the fish remains at normal temperatures, the beetles will migrate to this. Very well dried fish reduces the rate of increase of Dermestes populations.

Salting of fish gives protection against D. maculatus, partly because larval development is prolonged but mainly because larval mortality increases with increasing salt content. In experiments at 30°C, larval development took 37 days on fish with 3.5% salt content compared with 21 1/2 days on unsalted fish, and mortality reached 100% when the salt content was increased to 9.2% by brining for 1 1/2 h (Osuji, 1975 a). This susceptibility to salt may explain the less frequent occurrence of D. maculatus in cured marine fish, as salt is more commonly used in marine fish processing. D. ater is also adversely affected by salting. By contrast, D. frischii is relatively tolerant of salt. For example, Amos (1968) showed that, at 30°C and 75% r.h., the total development period of 34 days on unsalted fishmeal increased only to 42 and 53 days when the salt contents were 14% and 25%, respectively, though 60% salt content prevented development. However, in these experiments, the presence of salt even at 14% had a considerable effect on larval mortality and on egg-laying, and thorough salting can thus be used to control D. frischii. There are no reports of the response of other Dermestes species to salting.

4. LARDOGLYPHUS SPP.

Species of Lardoglyphus belong to the family Acaridae in the mite group Astigmata. Three species have been found infesting cured fish: L. konoi (Sasa and Asanuma); L. zacheri Oudemans; and L. angelinae Olsen. The commonest species is L. konoi.



Source: Adult and hypopus - adapted from Hughes (1976) by permission of the Controller of Her Majesty's Stationery Office, U.K. (Crown Copyright)

Figure 3. Dorsal view of adult female of *Lardoglyphus konoi* (left) and ventral view of hypopus of *L. zacheri* (right).

4.1 Specific and common names

L. konoi has occasionally been called the "Fish mite" [En]. No common names have been used for L. angelinae or L. zacheri.

4.2 Description and recognition features

ADULT - Appearance as in Figure 3 (left): oval-bodied with four pairs of legs. Length of body c. 0.3-0.6 mm; females larger than males. As in most acarid mites, the body is smooth and translucent creamish-white with several pairs of hairs, which are only visible under a good hand-lens or a low-power microscope. The females differ from other acarid mites found on stored food in having paired (rather than single) claws, and the males are distinctive because the third legs end in two blunt spines instead of claws: these characteristics of Lardoglyphus spp. are only visible with a high-power microscope. Precise identification of species requires specialist microscopic techniques and knowledge.

HYPOPUS - Apperance as in Figure 3 (right) when viewed from below. Length of body c. 0.2 mm. Legs rather stouter than those of adult. The body hairs are short, and are sometimes thickened into small spines. There are no functioning mouthparts. The underside of the body has numerous small suckers, especially concentrated on a sucker plate behind the bases of the fourth legs.

OTHER STAGES - The protonymph and tritonymph are similar in appearance to the adult but are smaller. The larva is smaller still, and has only three pairs of legs.

4.3 Life-cycle

Adults and nymphs of Lardoglyphus feed on drying or dried fish. The adult female lays eggs on the fish; after hatching into a six-legged larva, the mite passes through the eight-legged protonymph and tritonymph stages during its development into an adult. This development can be very rapid. At 23°C and 87% r.h. the life-cycles of L. konoi and L. zacheri take only 9-11 and 10-11 days, respectively; at optimum temperatures, development may be even faster. Potential rates of increase have not been estimated for these mites, but they are probably of the order of thousands of times per month under optimum conditions. In such situations, the mites can increase to vast numbers within a few days and, because moderate populations of Lardoglyphus are easily overlooked, a heavy infestation may seem to occur quite suddenly.

Some protonymphs do not change directly into tritonymphs, but instead turn into hypopi first. The hypopi do not feed but are a dispersal stage. They climb onto the larvae and adults of beetle pests, and use their suckers to attach themselves to the insect's cuticle. On larvae, they are found on the soft membrane between segments, especially near the front of the body; on adults, they are most commonly found on the upper surface of the abdomen under the elytra. They may remain on the insect for several days, and are therefore often carried to new infestation sites before they detach themselves and change into tritonymphs. Although Vijayambika and John (1974) have questioned the importance of environmental factors in controlling the production of hypopi, most investigators (e.g., Hughes, 1956; Matsumoto, 1970, 1973) have shown that the proportions of hypopi in Lardoglyphus populations are influenced by such factors as unfavourable temperature and humidity levels, or shortage of food, or overcrowding.

4.4 Ecology

Optimum conditions for the development of Lardoglyphus konoi are 30-35°C and 87% r.h. L. konoi cannot develop at 66% r.h. and below, but populations of this species increase at humidities of 75% and above (up to 98% r.h.). Little is known about the temperature and humidity responses of L. zacheri and L. angelinae, but they are probably similar to those of L. konoi. Lardoglyphus spp. can therefore become pests in many tropical and subtropical situations, especially where ambient conditions are humid or the fish is not well dried.

Infestations of Lardoglyphus spp. on cured fish are usually associated with those of Dermestes spp. and Necrobia rufipes. This is partly due to the similarities in the physical and nutritional requirements of all these pests, but it is mainly because the beetle pests are the main agents of dispersal of the Lardoglyphus hypopi.

4.5 Damage caused to cured fish

Feeding by the adults and nymphs of Lardoglyphus spp. will cause quantitative loss of dried cured fish. Quality loss may result from the contamination by live and dead bodies, which can be very numerous. The extent and value of losses caused to dried fish by Lardoglyphus spp. have not been assessed in either the laboratory or the field.

4.6 Ecological factors in relation to loss reduction

Initial infestation is often caused by hypopi that have been carried to the fish by beetle pests. The techniques given in sections 2.6 and 3.6 for reducing initial infestation by beetles will therefore also reduce infestation by Lardoglyphus spp. Fragmentation of the fish flesh, caused by beetle and fly attack and by handling damage, increases the surface area of the flesh and may thus encourage heavier mite infestations.

The minimum humidity threshold for Lardoglyphus konoi is between 66% and 75% r.h. If the fish is thoroughly dried, mite problems will be greatly reduced or eliminated. The temperature limits for development are not known, but temperatures above 40-45°C would be expected to kill these mites.

The response of Lardoglyphus spp. to salt has not been investigated. L. konoi has been found infesting salted fish products as well as unsalted dried fish, but the salt contents of the infested products were not recorded.

5. DIPTERA

Most flies found on cured fish belong to the subfamilies Calliphorinae and Sarcophaginae in the family Calliphoridae. The commonest of these are various species of Chrysomya, but Calliphora, Lucilia, Sarcophaga and Wohlfartia have also been reported. Other families represented in records of flies infesting cured fish are: Muscidae (Antherigona, Musca and Ophyra); Piophilidae (Piophila); Milichidae (Leptometopa); Phoridae (Megaselia); and Ephydridae (Discomyza). All these flies are rather similar in general form, though they show a variety of size and coloration, and their identification requires specialist knowledge.

Source: Adult and larva - by permission of Ministry of Agriculture, Fisheries and Food, U.K. (Crown Copyright)

Figure 4. Dorsal view of adult of *Calliphora vicina* (top) and lateral view of larva of *Piophila casei* (bottom).

5.1 Scientific and common names

Diptera: Flies [En]; Mouche [Fr]; Zweiflügler [Ge]; Mosca [Sp]. The class Diptera includes the families in Table 2; the genera and species listed in the Table are those recorded from cured fish by Haines (1974, 1981), FAO (1981), and Overseas Development Natural Resources Institute (unpublished records).

Table 2. Families, genera and species of flies found on cured fish.

Family Calliphoridae, subfamily Calliphorinae: Blowflies, Bluebottles, Greenbottles, Screw-worms [En]; Mouche à viande, Mouche verte de la viande [Fr]; Schmeißfliege [Ge]; Moscarda corónida, Corónida [Sp]. Includes: *Calliphora* spp.; *Chrysomya albiceps* Wiedemann; *C. bezziana* Villeneuve; *C. chloropyga putoria* (Wiedemann); *C. megacephala* (Fabr.); *C. regalis* Desvoidy, *Lucilia cuprina* Wiedemann; and *L. sericata* Meigen.
Family Calliphoridae, subfamily Sarcophaginae: Flesh flies [En]. Includes: *Sarcophaga* spp.; *S. nodosa* Engel; *S. tibialis* Macquart; and *Wohlfartia* spp.
Family Ephydridae: Shore-flies [En]. Includes: *Discomyza maculipennis* Wiedemann.
Family Milichidae. Includes: *Leptometopa latipes* (Meigen).
Family Muscidae. Includes: *Anthérigona* spp.; *Ophyra capensis* Wiedemann; and *Musca domestica* L. (House fly [En]; Mouche commune, Mouche domestique, Mouche des maisons [Fr]; Stubenfliege, Hausfliege [Ge]; Mosca casera, Mosca doméstica, Mosca común [Sp]).
Family Phoridae. Includes: *Megaselia scalaris* (Loew).
Family Piophilidae: Bacon-flies [En]. Includes: *Piophila casei* (L.) (Cheese hopper, Cheese maggot, Cheese skipper [En]; Mouche du fromage [Fr]; Käsefliege [Ge]; Mosca del queso [Sp]).

5.2 Description and recognition features

ADULT - The many different species of fly found on cured fish all have the same general form, as shown in Figure 4 (top). Length 2.5-15.0 mm, depeding on species. Colour of body often black and grey but many of the common species have a metallic green, blue or purple sheen on the upper surface. The eyes are large. The two fore-wings are membranous and transparent, but the hind-wings are modified into small club-like halteres. Identification of the many species requires specialist knowledge.

LARVA - General form usually as shown in Figure 4 (bottom). Length varies greatly, depending on species and stage of growth. Body generally cylindrical, but often tapering towards the head, and sometimes with numerous

protuberances that may act as false legs (not present in the species illustrated in Figure 4). Colour usually greyish-white or creamish. Distinguished from all other pests found on cured fish by their lack of jointed legs, their very small head, and the reduced mouthparts (mainly consisting of two hook-like mandibles). Differentiation of the species is very difficult, even with specialist knowledge, and specimens of fly larvae collected for identification should therefore be kept alive until they become adults.

5.3 Life-cycle

Adult female flies lay their eggs (or, in some species, small larvae), usually in batches, on the flesh of fish. Flies in the families Calliphoridae, Ephydridae and Muscidae only infest moist fish in the early stages of the curing process; those in the families Milichidae, Phoridae and Piophilidae can infest partially and fully cured fish. The larvae (usually known as maggots) feed on the surface of the flesh and may also burrow deeply into it. In moist fish, particularly, the burrowing can cause serious fragmentation. The larvae of Calliphoridae and Muscidae often tend to aggregate in discrete areas, where they cause severe damage. There are only three larval instars in the types of fly found on cured fish. Larval development of the major fly pests of moist fish can take as little as three days. At pupation, the last larval skin is retained and modified to form a hard protective puparium. Larvae that infest moist fish usually leave the fish in order to pupate, and often burrow into the soil beneath drying racks or mats. The emerging adults are, of course, strong fliers and quickly disperse to new sources of suitable food. The life-cycle of the main pest species of moist fish (notably Chrysomya spp. and other Calliphoridae) can be completed in about seven days under suitable conditions. The species that infest dried fish develop more slowly: e.g., under ambient conditions in Malawi, Piophila casei completes its life-cycle in about 20 days.

5.4 Ecology

Larvae of Calliphoridae, Ephydridae and Muscidae require a high moisture content for development and cannot infest fully cured fish. The moisture requirements of the other flies listed in Table 2 are not known, though Leptometopa latipes develops more quickly on poorly dried fish, whereas Piophila casei can develop on well dried fish.

Little is known about the effect of temperature on fly adults and larvae, but the larvae seem to be relatively tolerant of hot conditions, compared with beetle and mite pests. For example, although infestation by blowfly larvae is reduced at temperatures in excess of 45°C, complete kill requires 20 h at such temperatures: Piophila casei is particularly tolerant of high temperatures: in experiments, all larvae survived 1 h at 52°C and 24 h at 45°C (Smart, 1935).

The larvae of several of the species can cause myiasis in man or livestock: i.e., they may infect surface wounds, or they may be ingested and continue to develop as parasites in the intestine. Adult flies of most pest species are attracted to rotting material (such as decomposing fish offal) and dung, where they may feed and breed. They may thus transmit pathogenic bacteria when they lay eggs on the fish.

5.5 Damage caused to cured fish

The feeding of the larvae of Calliphoridae on moist fish causes quantitative losses. These losses can be severe if conditions are optimal for fly development: under such conditions, i.e., if unsalted or poorly salted fish is dried slowly because of rain or high humidity, weight losses of 10-30% can be caused by fly larvae. Fragmentation of the fish by fly attack can cause quality loss and may lead to increased risk of damage by beetles and mites. Substantial weight losses due to fragmentation of fish during processing have been recorded, but the contribution of blowfly damage to this has not been separately assessed. Additional costs are implicated in the role of flies as the agents of myiasis and as carriers of pathogens.

5.6 Ecological factors in relation to loss reduction

Initial infestation is due primarily to flying adults. Fly-screens around and over drying racks may reduce infestation pressure during drying. The risk of cross-infestation can be reduced by treatment of the ground beneath drying racks and mats (where flies often pupate) with a recommended insecticide. Improved hygiene at fish processing sites, especially the rapid disposal of wet offal, will reduce fly infestation problems by removing a secondary food source.

The most important fly pests only infest and damage the fish while it is drying. The length of the drying period is thus a critical factor influencing the extent of losses due to fly attack, and any measures that increase the speed of drying of fish will also reduce fly damage.

Thorough and heavy salting provides complete protection against blowfly larvae. The precise effects of lower salt contents have not been studied, although it is known that poor salting techniques allow blowfly attack. The effects of salt on other types of flies have not been investigated.

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